PATENT ABSTRACTS OF JAPAN

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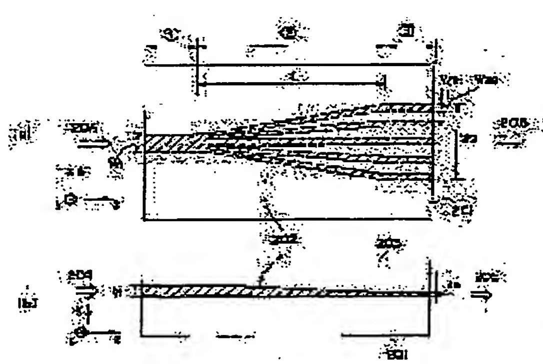
(54) **OPTICAL COUPLING DEVICE**

(57)Abstract:
PURPOSE: To provide an optical coupling device whose productivity is excellent and capable of accomplishing optical coupling between two different optical functional elements, especially between the optical functional elements which are obtained by integrating plural devices at a small loss.

CONSTITUTION: As to the optical coupling device constituted of at least a semiconductor substrate 201 and optical waveguide layers 202 and 203 which are formed on the semiconductor substrate 201 and whose size and refractive index are gradually varied in a light transmission direction, the optical waveguide layers 202 and 203 are branched near a light incident end, or a light emitting end and arranged. Thus, the optical coupling is accomplished at a small loss.



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CLAIMS

[Claim(s)]
[Claim 1] The optical coupling device characterized by carrying out branching arrangement of this lightguide at plurality in an optical incidence edge or near an optical outgoing radiation edge in the optical coupling device which consists of lightguides to which it is formed on a semi-conductor substrate and this semi-conductor substrate, and magnitude or a refractive index was gradually changed along the optical propagation direction at least.
[Claim 2] The optical coupling device according to claim 1 characterized by distributing spatially the width of face of said lightguide arranged to plurality, or spacing of said waveguide.
[Claim 3] The optical coupling device according to claim 1 or 2 characterized by constituting the thickness of a lightguide from fixed thickness in the travelling direction of light.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the optical coupling device which changes into other optical functional devices the spot size of the light wave transmitted in the optical waveguide of an optical functional device by low loss.
[0002]
[Description of the Prior Art] Since mutual optical waveguide light wave spot size differs if direct matching association (butt joint) of the fiber is carried out to LD component end face when carrying out optical coupling of between a semiconductor laser diode (LD) and single mode fibers, joint loss of the direct matching section becomes a problem. Usually, since the light wave spot size (mode radius: W) of LD is about 1 micrometer and the spot size of a fiber is about 5 micrometers, this joint loss is set to about 10dB. Then, generally the method of reducing joint loss is taken by changing spot size with a lens.
[0003] The conventional example of a configuration is shown in drawing 5 about the case where optical coupling of between the optoelectronic devices and the array fibers in which two or more laser diodes (LD) were formed is carried out with one lens. It sets to drawing 5 and is 501. A semi-conductor substrate and 502 An active region (optical waveguide section) and 503 A fiber and 504 V-groove array for fixing a fiber at fixed spacing, and 505 It is a lens. In such a configuration, since joint loss became large under the effect of the aberration of a lens etc. as the accumulation scale of LD becomes large, the number of LD accumulable on one semi-conductor substrate had a limit.
[0004] There is a method of making low loss carry out optical coupling of between fibers to LD by using the optical coupling device which changes the spot size of light by the optical waveguide of the shape of a taper as shown in drawing 6 as a substitute of a lens. Drawing 6 (a) The plan of the conventional optical coupling device, and (b) A sectional view and drawing 7 are drawings for explaining the principle of operation. That is, it is the core layer 602 of optical waveguide so that drawing 7 may show. Refractive-index difference deltan[= (n1-n2) / n1, n1 : Cladding layer 601,603 A refractive index, n2 : Core layer 602 When refractive-index] is fixed to fixed magnitude, it is a core layer 602. If thickness t and width of face w are gradually enlarged from 0 After the spot size W of guided wave light (basic-mode light) becomes gradually small from the magnitude of infinity and takes the minimal value, it has the relation it is large unrelated again. Here, since it will become multi-mode waveguide and loss by higher-mode conversion will become large if t and w become large too much, the dimension of this field is not usually used. This relation is used and it is the core layer 602 of an optical coupling device. In the design of magnitude t and w Spot size Wi comparable as the spot size (about 1 micrometer) of LD light in optical incidence one end (association side with LD) To the dimension wi to give and ti (100nm of = numbers -, number mum) Magnitude spot size Wo comparable as the spot size (about 5 micrometers) of a fiber in optical outgoing radiation one end It is set as the dimension to to give and wo (-ten = number - 100nm of numbers) (about the example of a concrete design, they are 1992 ********** size, C-201, and 1991., for example reference). Moreover, die-length L of the field where the magnitude of a core layer 602 becomes taper-like is -100 in order to reduce loss by radiation. It is set as die length of several mm or more from mum.
[0005]

[Problem(s) to be Solved by the Invention] It sets in such a configuration and they are the dimension to of optical outgoing radiation one end, and wo. It is made small and is spot size Wo. If it enlarges, since it will be in the weak condition of optical confinement, the optical intensity distribution of waveguide become an exponential-function configuration. On the other hand, since the guided wave light intensity distribution of an optical fiber are Gaussian distribution configurations mostly, the joint loss by the mismatching of a configuration arises theoretically. Moreover, optimal to for acquiring low joint loss and wo Since the amount of dimension fluctuation permitted is comparatively small, when using the usual method of construction, there is also a difficulty on manufacture.

[0006] Also by making magnitude of deltan small gradually along the travelling direction of light, and on the other hand, enlarging t and w gradually in connection with it, spot size is expandable so that drawing 7 may show. However, it is difficult to change a refractive index in the shape of a taper, and to form it small enough at an optical outgoing radiation edge in this case, and there was a fault which cannot realize a low loss property. The purpose of this invention is to offer the good optical coupling device of manufacture nature which can take optical coupling for between two different optoelectronic devices, especially the optoelectronic device which integrated two or more devices by low loss.

[0007]

[Means for Solving the Problem] In order that this invention might solve the above-mentioned technical problem, in claim 1, it was formed on the semi-conductor substrate and this semi-conductor substrate, and carried out branching arrangement of this lightguide in an optical incidence edge or near an optical outgoing radiation edge at plurality in the optical coupling device which consists of lightguides to which magnitude or a refractive index was gradually changed along the optical propagation direction at least. Moreover, in claim 2, the width of face of said lightguide arranged to plurality at least or spacing of said waveguide was spatially distributed in claim 1. Moreover, in claim 1 or 2, fixed thickness constituted the thickness of said lightguide from claim 3 in the travelling direction of light.

[0008]

[Function] In this invention, low loss optical coupling is realized by carrying out branching arrangement of the lightguide at plurality.

[0009]

[Example] Hereafter, the example of this invention is explained to a detail with reference to a drawing. Drawing for drawing 1 , one example of the optical coupling device according [drawing 2] to this invention, and drawing 3 to explain the principle of this invention and drawing 4 are other examples of this invention.

[0010] Drawing 1 (a) and (b) are the block diagrams in the case of the example of the optical coupling device by this invention being shown, inserting the optical coupling device of this invention between an array LD component and a fiber, and taking optical coupling to low loss. Drawing 1 (a) A plan and (b) It is the semi-conductor substrate of the optical coupling device which is a sectional view and 101 requires for this invention, and 102. A core layer and 103 A cladding layer and 104 It is an antireflection film. In addition, 105 An optical fiber and 106 It is V groove array. By this configuration, it is the core layer 102 of an optical coupling device. Magnitude was changed gradually and it has changed into suitable size from the light wave spot size of LD in the optical outgoing radiation section.

[0011] drawing 2 (a) The plan of one example of this invention for taking the optical coupling between one LD component and one fiber, and (b) the sectional view of a core -- it is -- 201 For example, InP etc. -- the semi-conductor substrate (refractive index n1) constituted and 202 The waveguide core layer for spot-size conversion (for example, InGaAsP and a refractive index n2), and 203 It is a semi-conductor cladding layer (for example, InP and a refractive index n3). The magnitude of these refractive indexes is n1 and n3 <n2. It is related. 204 The incident light from ** LD, and 205 It is the outgoing radiation light to which the single-mode-optical-fiber side was expanded. In the optical waveguide section of field ** in drawing, it has the usual waveguide structure of having the spot size of the almost same magnitude as the light wave spot size of LD. At field **, it is a core layer 202. Branching arrangement is carried out at plurality, and when direct

optical coupling is carried out to a fiber, the structure of waveguide and the magnitude of dimensions w and t and a refractive index n are set up so that it may become the expanded spot size and the configuration of acquiring a low loss joint property. In field **, as spot size is changed gradually, the effectual waveguide width of face w is formed in the shape of a taper, and the die length of the taper is L.

[0012] Hereafter, the principle of this invention is explained. Drawing 6 (a) and (b) In the taper waveguide of the shown conventional spot-size conversion, since magnitude of a core is made extremely small in order to expand spot size, a mode field configuration becomes exponential function-like. However, spot size can be enlarged, even if it does not make w and t small so that drawing 7 may show, when refractive-index difference deltan is made small. If it follows on making deltan small at this time and w and t are made into suitable magnitude, since it will be maintained at the condition of optical waveguide having shut up and having enlarged the multiplier, a mode field configuration becomes Gaussian [-like] like the usual single mode fiber. In this invention, as shown in drawing 2 , it sets to field **, and it is the total waveguide width of face w3. It is made magnitude comparable as the diameter of a core of a fiber, and is a core layer 202. By setting width of face w31 and the spacing w32 between core layers as a suitable dimension, it is n2. Effectual deltan of optical waveguide is made small, without changing magnitude. By this, it is the semi-conductor substrate 201. Since the spot size of field x direction is expanded, joint loss with a fiber can be reduced.

[0013] Drawing 3 is the waveguide structure of field **, and the x direction mode coupling effectiveness eta x between these waveguide-fibers. The rough value of relation is shown. here -- the wavelength of light -- lambda= 1.55 the refractive index of mum, a core, and a cladding layer -- n2=3.3 and n1 =n3 =3.17 -- being fixed -- carrying out -- the mode radius of a fiber -- wf=4.5 mum -- it is -- core layer 202 a degree -- five -- w31+w -- it was presupposed that it is fixed 32= 2 micrometers. As shown in this Fig., when the core width of face w31 (dx) and core thickness t3 (= dy) are made into predetermined magnitude, it turns out that fiber joint loss can be made very small (0.1dB or less). In addition, the mode field configurations of a substrate side and a perpendicular direction (the direction of y) have become exponential function-like at this time, and joint loss in the direction of y has magnitude [being comparable as the conventional example (0.2dB)]. Therefore, all joint loss with a fiber is 0.3dB. It is made to below. Furthermore, the core dimensions w31 and w32 are made small, the branching number is increased, and it is full [w3]. By setting it as suitable magnitude so that it may double with the mode field configuration of a fiber, joint loss can be made still smaller. Such structures can be correctly designed by analyses, such as the finite element method. In this invention, the waveguide of field ** or field ** is removed at least, and even if constituted only from waveguide of field **, the same property is realizable.

[0014] In addition, when making the optical waveguide by this invention, it is n1, n2, and n3. Magnitude can be set as arbitration by choosing a semiconductor material. For example, it is InP to a cladding layer. When it uses, it is wavelength lambda= 1.55. To the light of mum band, it is n= 3.166. moreover, the refractive index of InGaAsP -- the presentation -- about 3.2 from -- 3.5 It can be set as the magnitude of arbitration to extent. Moreover, a refractive index can be set as arbitration by choosing the quality of the material and thickness of a well layer and a barrier layer, using a multiplex quantum well layer as a core layer. Moreover, it is a core layer 202 by using a selective growth mask, an epitaxial selective growth technique or a photolithography technique, etc., for example. Refractive index n2 The magnitude of the waveguide dimensions w and t can also be spatially set up and manufactured in the shape of a taper.

[0015] In order to realize the optimal core dimension for acquiring the best joint loss in drawing 2 , it is the core thickness t3. For example, it can manufacture with a sufficient precision with a crystal epitaxial growth technique. A core layer width w31 is understood that it can manufacture easily with the usual photolithography technique from the amount of permission fluctuation being comparatively large. Moreover, it is also possible to make core layer thickness t regularity (t1 =t3) over field **, **, and ** whole region, and to make it the structure where only core layer width w was transformed, and a manufacture process becomes simple in this case.

[0016] Drawing 4 is the plan of other examples of this invention, and is the case where joint loss which made the mode field configuration in agreement from that of a fiber is reduction-ized, by giving distribution to the magnitude of the core width of face w31 of field **. Moreover, it is

obvious by giving distribution for the magnitude of the core spacing w32 spatially that the same effectiveness can be acquired.
[0017] In the case of the same die length, L can make radiation loss comparatively small by making a taper configuration into the shape of a straight line like drawing 2 as a configuration of the taper section of field **, or making it curvilinear configurations, such as the shape of an exponential function, and parabolic. Moreover, it is easy to be even if it makes it a joint branching configuration like a letter of branching like drawing 2 , or drawing 4 as a method of branching a core layer.
[0018] Above, it is the total waveguide width of face w3 of field **. Although the case where it was made the diameter of a core and comparable magnitude (usually w1 <w 3) of a fiber was explained, it is this w3. It is the waveguide width of face w1 of field ** about magnitude. As comparable, the spot size of this field is expandable by setting w31 and w32 as suitable magnitude. However, although a mode field configuration becomes exponential function-like in this case, it is obvious that low loss fiber optical coupling is realizable like the conventional example.
[0019] although the case where the waveguide for spot-size conversion was constituted on an In P substrate was explained above -- other semiconductor materials, for example, a GaAs system, or SiO 2 etc. -- it is obvious that the same effectiveness can be acquired also to the optical waveguide of a textile-glass-yarn ingredient. Moreover, although the case where made the same the quality of the material of the substrate ingredient which becomes the clad section of optical waveguide, and a cladding layer, and it constituted from a core layer of a monolayer was explained above, the principle same also about the thing which combined an ingredient which is different in these clads, or the thing constituted from two or more core layers as this invention can be used. Although the case where an optical fiber was connected was explained above, in addition if the structure of the optical coupling device waveguide by this invention is suitably set up also to a connection with all optical waveguide components, such as other semi-conductor optical waveguide components or glass waveguide components, so that it may double with the optical intensity distribution of these waveguides, it is obvious that the property of low joint loss is realizable.
[0020] Since this optical coupling device consists of semiconductor materials, it is also possible to, realize the optical device which carried out monolithic integration of this joint device on the same substrate for example, at the optical incidence edge of optoelectronic devices, such as semiconductor laser, and LD amplifier, an optical switch. In this case, when forming optoelectronic device waveguide, after forming the waveguide for these optical coupling in coincidence or forming the optoelectronic device section on a semi-conductor substrate, the taper waveguide for optical coupling may be formed so that mutual waveguide may be compared directly.
[0021]
[Effect of the Invention] As explained above, in this invention, low loss optical coupling is made realizable by forming the magnitude of the semi-conductor layer which becomes the core section of optical waveguide, or a refractive index in the shape of a taper, and carrying out branching arrangement of the core semi-conductor layer in near the end face linked to other optoelectronic devices at plurality.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] It sets in such a configuration and they are the dimension to of optical outgoing radiation one end, and wo. It is made small and is spot size Wo. If it enlarges, since it will be in the weak condition of optical confinement, the optical intensity distribution of waveguide become an exponential-function configuration. On the other hand, since the guided wave light intensity distribution of an optical fiber are Gaussian distribution configurations mostly, the joint loss by the mismatching of a configuration arises theoretically. Moreover, optimal to for acquiring low joint loss and wo Since the amount of dimension fluctuation permitted is comparatively small, when using the usual method of construction, there is also a difficulty on manufacture.
[0006] Also by making magnitude of deltan small gradually along the travelling direction of light, and on the other hand, enlarging t and w gradually in connection with it, spot size is expandable so that drawing 7 may show. However, it is difficult to change a refractive index in the shape of a taper, and to form it small enough at an optical outgoing radiation edge in this case, and there was a fault which cannot realize a low loss property. The purpose of this invention is to offer the good optical coupling device of manufacture nature which can take optical coupling for between two different optoelectronic devices, especially the optoelectronic device which integrated two or more devices by low loss.

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MEANS

[Means for Solving the Problem] In order that this invention might solve the above-mentioned technical problem, in claim 1, it was formed on the semi-conductor substrate and this semi-conductor substrate, and carried out branching arrangement of this lightguide in an optical incidence edge or near an optical outgoing radiation edge at plurality in the optical coupling device which consists of lightguides to which magnitude or a refractive index was gradually changed along the optical propagation direction at least. Moreover, in claim 2, the width of face of said lightguide arranged to plurality at least or spacing of said waveguide was spatially distributed in claim 1. Moreover, in claim 1 or 2, fixed thickness constituted the thickness of said lightguide from claim 3 in the travelling direction of light.

[Translation done.]

OPERATION

[Function] In this invention, low loss optical coupling is realized by carrying out branching arrangement of the lightguide at plurality.

[Translation done.]

* NOTICES *

EXAMPLE

[Example] Hereafter, the example of this invention is explained to a detail with reference to a drawing. Drawing for drawing 1 , one example of the optical coupling device according [drawing 2] to this invention, and drawing 3 to explain the principle of this invention and drawing 4 are other examples of this invention.
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[0014] In addition, when making the optical waveguide by this invention, it is n1, n2, and n3. Magnitude can be set as arbitration by choosing a semiconductor material. For example, it is InP to a cladding layer. When it uses, it is wavelength lambda= 1.55. To the light of mum band, it is n= 3.166. moreover, the refractive index of InGaAsP -- the presentation -- about 3.2 from -- 3.5 It can be set as the magnitude of arbitration to extent. Moreover, a refractive index can be set as arbitration by choosing the quality of the material and thickness of a well layer and a barrier layer, using a multiplex quantum well layer as a core layer. Moreover, it is a core layer 202 by using a selective growth mask, an epitaxial selective growth technique or a photolithography technique, etc., for example. Refractive index n2 The magnitude of the waveguide dimensions w and t can also be spatially set up and manufactured in the shape of a taper.
[0015] In order to realize the optimal core dimension for acquiring the best joint loss in drawing 2 , it is the core thickness t3. For example, it can manufacture with a sufficient precision with a crystal epitaxial growth technique. A core layer width w31 is understood that it can manufacture easily with the usual photolithography technique from the amount of permission fluctuation being comparatively large. Moreover, it is also possible to make core layer thickness t regularity (t1 =t3) over field **, **, and ** whole region, and to make it the structure where only core layer width w was transformed, and a manufacture process becomes simple in this case.
[0016] Drawing 4 is the plan of other examples of this invention, and is the case where joint loss which made the mode field configuration in agreement from that of a fiber is reduction-ized, by giving distribution to the magnitude of the core width of face w31 of field **. Moreover, it is obvious by giving distribution for the magnitude of the core spacing w32 spatially that the same effectiveness can be acquired.
[0017] In the case of the same die length, L can make radiation loss comparatively small by making a taper configuration into the shape of a straight line like drawing 2 as a configuration of the taper section of field **, or making it curvilinear configurations, such as the shape of an exponential function, and parabolic. Moreover, it is easy to be even if it makes it a joint branching configuration like a letter of branching like drawing 2 , or drawing 4 as a method of branching a core layer.
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principle same also about the thing which combined an ingredient which is different in these clads, or the thing constituted from two or more core layers as this invention can be used. Although the case where an optical fiber was connected was explained above, in addition if the structure of the optical coupling device waveguide by this invention is suitably set up also to a connection with all optical waveguide components, such as other semi-conductor optical waveguide components or glass waveguide components, so that it may double with the optical intensity distribution of these waveguides, it is obvious that the property of low joint loss is realizable.

[0020] Since this optical coupling device consists of semiconductor materials, it is also possible to, realize the optical device which carried out monolithic integration of this joint device on the same substrate for example, at the optical incidence edge of optoelectronic devices, such as semiconductor laser, and LD amplifier, an optical switch. In this case, when forming optoelectronic device waveguide, after forming the waveguide for these optical coupling in coincidence or forming the optoelectronic device section on a semi-conductor substrate, the taper waveguide for optical coupling may be formed so that mutual waveguide may be compared directly.

[Translation done.]

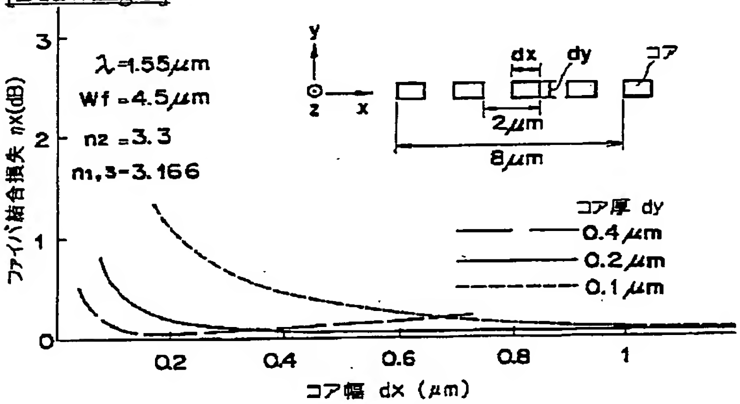
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The plan and sectional view showing the example of 1 configuration of the optical coupling device by this invention
[Drawing 2] The plan and sectional view showing the example of 1 configuration of the optical coupling device by this invention
[Drawing 3] Drawing in which showing the principle of operation of this invention, and having shown the relation between the structure of waveguide, and fiber joint loss
[Drawing 4] Drawing showing other examples of a configuration of the optical coupling device by this invention
[Drawing 5] Drawing having shown the conventional optical coupling approach
[Drawing 6] Drawing having shown the structure of the conventional optical coupling device
[Drawing 7] The explanatory view of the principle of operation of the optical coupling device of drawing 6
[Description of Notations]
101,201,401 -- semi-conductor substrate and 102,202,402 -- A core layer and 103,203,403 -- A cladding layer and 204,404 -- An incident wave and 205,405 -- Hikaru Idei.

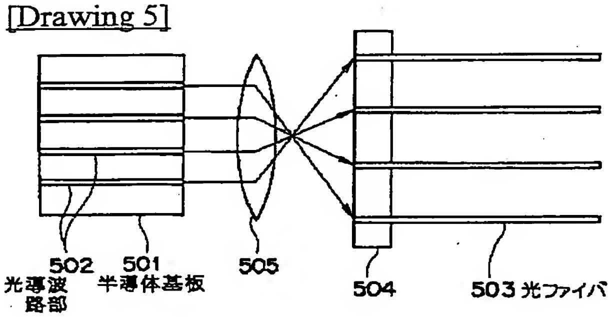
[Translation done.]

DRAWINGS

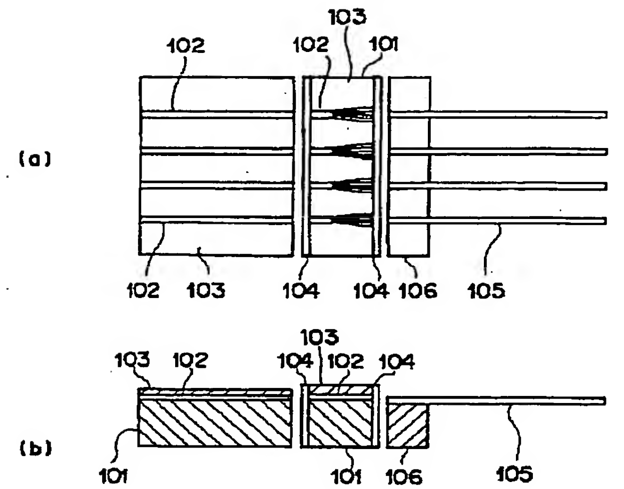
[Drawing 3]



[Drawing 5]

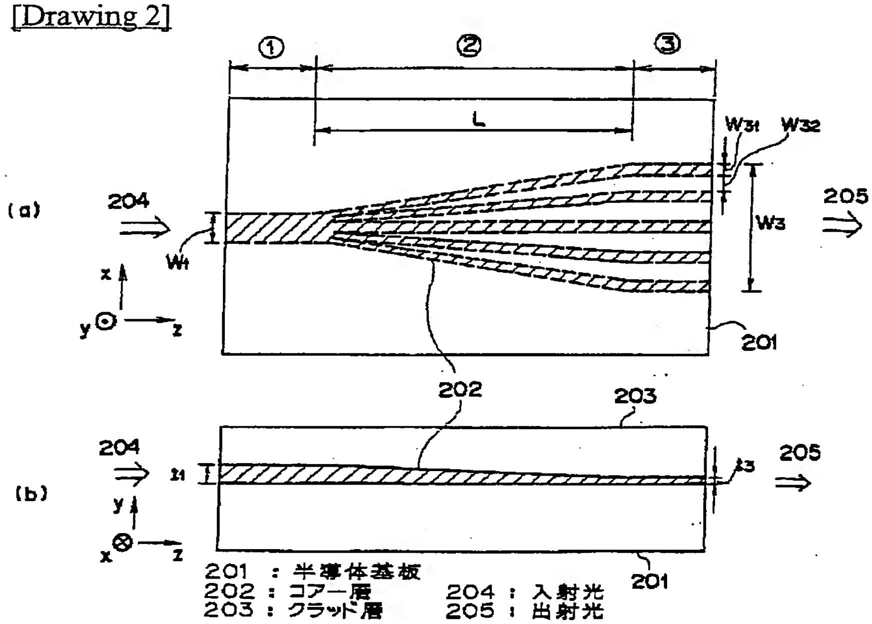


[Drawing 1]

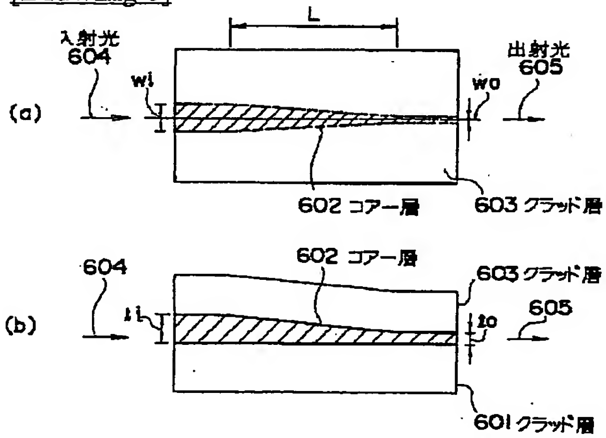


101 : 半導体基板
102 : コアー層
103 : クラッド層
104 : 反射防止膜

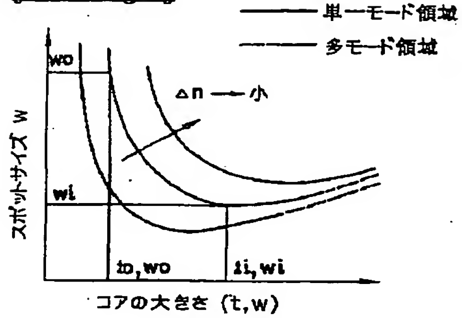
[Drawing 2]



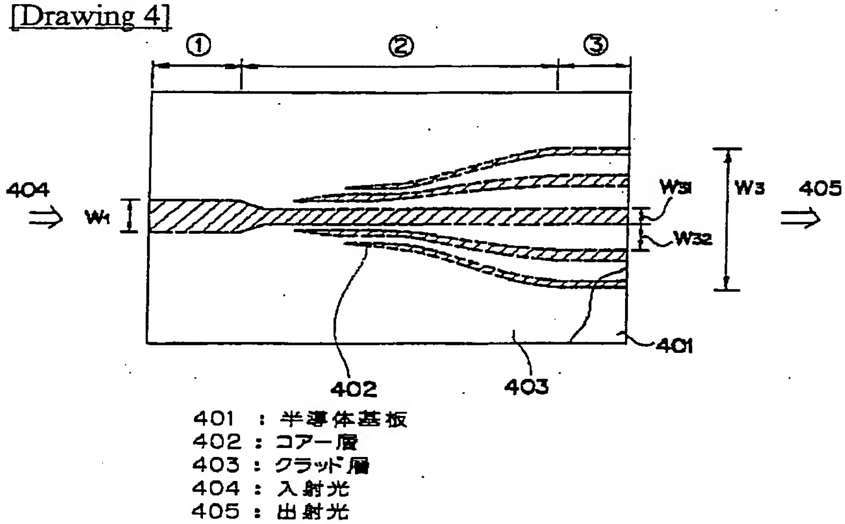
[Drawing 6]



[Drawing 7]



[Drawing 4]



[Translation done.]